RAND HYDROGEN

Erapooletu vaade vesinikule tehniliselt ja majanduslikult

Teemad

- Minust ja meist
- Sissejuhatus
- Vesinik numbrites
- Vesiniku praktilisus
- Vesiniku tootmine, pakendamine ja tarbimine
- Vesiniku hinna kujunemine
- Turvalisus
- Levinumad müüdid

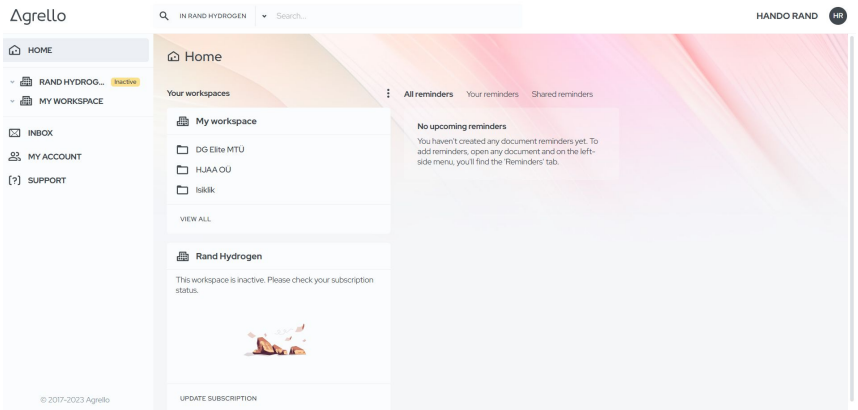
01

Minust ja meist

RAND HYDROGEN

Agrello

PowerUP®
ENERGY TECHNOLOGIES



Disclaimerid

- Ei ole inseneri kvalifikatsiooniga
- Ei ole keemik
- Ei ole füüsik
- Hoopis TTÜ õigusteaduse BA

Rand Hydrogen

5-liikmeline meeskond kelle eesmärk on saavutada:

- Tehniline KnowHow ja kogemus
- Valmisolek 0 emissiooni nõueteks
- Tehnomajanduslikud analüüsid
- Lahendused odava energia rakendamiseks (Tuul)
- Muud uued energialahendused


HYZON


RAND HYDROGEN


759


AFLATEK


FINAVI
H2
HYZON
FINAVIA
Vammas


CAETANO
EY-2487

02

Sissejuhatus

RAND HYDROGEN

Kontekst

Selles esitluses

Elektromagneetiline vastastikmõju

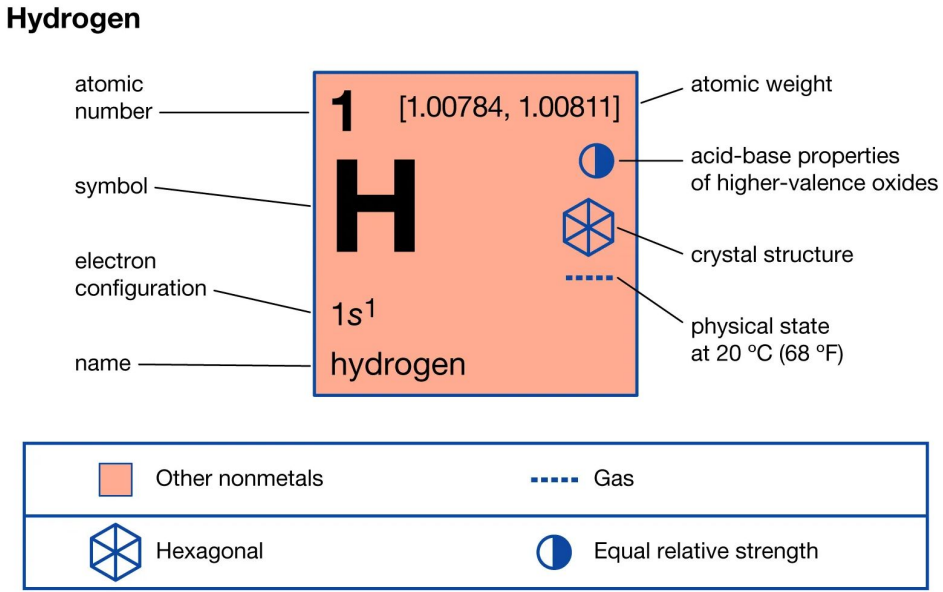
- Põlemine
- Elektrokeemia
- Keemiatööstus

Mitte selles esitluses

Tugev vastastikmõju

- Tuumasünteesienergia
- Vesinikpommid

ABOUT HYDROGEN



- Kergeim element ja molekul
- Kõige levinum element universumis (Ei ole majanduslik argument)
- Vähe ebavajalikkku massi, kuid väga kitsi elektrone ligi laskma
- Looduslikult võiks olla H2, aga meil ei ole.
- Kõigis naftakütustes ja ammoniaagis.
- H+ tekib lihastes väga intensiivse treeningu tagajärjel

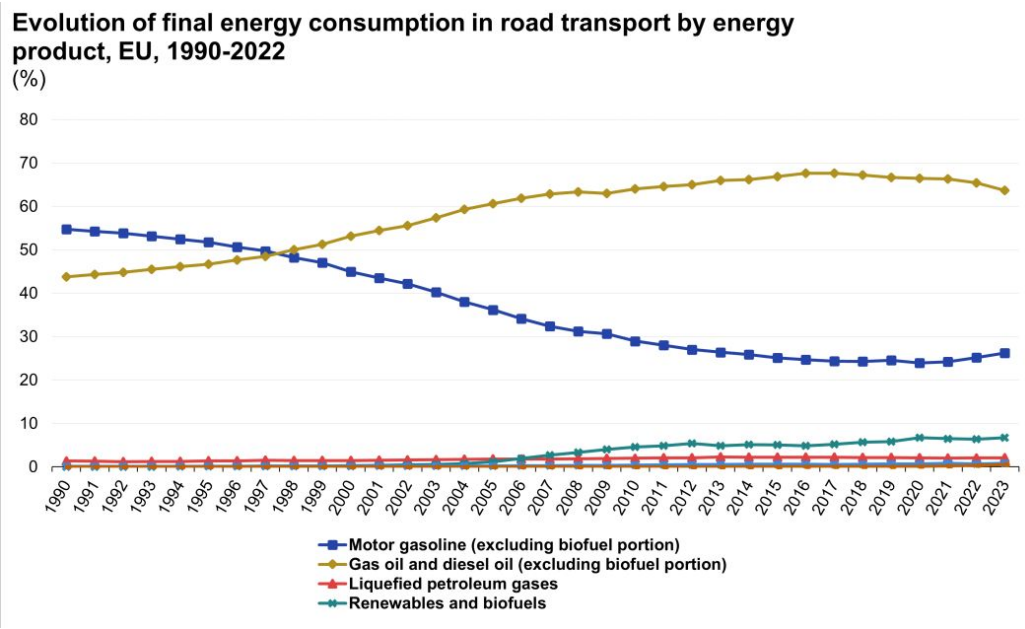
Ülevaatlikult

Minu hinnangul vesinik:

- ei ole silver bullet
- ei ole energiaallikas
- on energiakandja
- on üks tööriist energeetika ülesehitusel
- on ainuke toodetav mittederivaatne süsinikuheitmeta kütus.
- ei ole ühtmoodi kallis või odav

Miks teemaks?

Transpordisektoris on taastuvenergia kasutus alla 10%



Allikad:
https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Final_energy_consumption_in_transport_-_detailed_statistics

Miks teemaks?

- Üle poole oma energiavajadusest EL impordib.
- Suurem probleem on see transpordis.
- Vesiniku kütuseelement on kõige efektiivsem valik sõiduki liigutamiseks pärast BEV-sid.
- Vesinikku saab kiirelt tankida.

Allikad:
https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_overview#:~:text=planned%20article%20update-,Highlights,by%207.2%25%20compared%20with%202022.

Miks teemaks?

- Vesinikku saab igal pool Euroopas toota
- Läänemere piirkonnas on võimekus paigaldada üle 200 GWh tuuleenergia võimsust.
- Sellise võimsusega vesinikkütust tootes (offgrid) saaks katta mitmekordselt Läänemere äärse transpordisektori energiavajaduse.
- Tuuma- ja muid elektrijaamu saab ehitada, aga energiat on vaja transportida.

Allikad:
https://swedishwindenergy.com/wp-content/uploads/2025/02/SWEA-Statstics-and-Forecast-Q4-2024-1.pdf
https://www.sweco.fi/en/energy/wind-power/wind-power-in-finland/?utm_source=chatgpt.com
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03

H2 numbrites

RAND HYDROGEN

Vesinik kütus normaaltingimustel võrreldes teistega

01

Vesinikkütus

Süttimisenergia: 0.02mJ

Energia/kg: 33.3kWh(LHV)

Energia/Nm3: 3kWh/m3

Põlemistemperatuur: 2200C

Leegikiirus: 1.85 m/s

02

Metaan

Süttimisenergia: 0.3mJ

Energia/kg: 13.9kWh(LHV)

Energia/Nm3: 10kWh/m3

Põlemistemperatuur: 1950C

Leegikiirus: 0.38 m/s

03

Diisel

Süttimisenergia: 1000mJ

Energia/kg: 12.6kWh(LHV)

Energia/Nm3: 10700kWh/m3

Põlemistemperatuur: 2300C

Leegikiirus: 0.9 m/s

04

Mootoribensiin

Süttimisenergia: 80MJ

Energia/kg: 12.5kWh(LHV)

Energia/Nm3: 9300kWh/m3

Põlemistemperatuur: 1000C

Leegikiirus: 0.4m/s

03

Praktilisus

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Praktiline lähenemine

- Vesinik ei vaja usku, ega ole religoon
- Vesinik vajab arvutusi
- Praeguses olukorras, on väga keeruline leida mõistlikke kohti vesiniku tootmiseks ja tarbimiseks. (Tarbimis- ja tootmiskohtade vaheline distants)

Praktiline lähenemine

- Vesinik sinna, kus on energiat üle
- Vesinik sinna, kus on energiat üle pidevalt, mitte hooajaliselt
- Tehnoloogia CAPEx ei ole enam probleem
- Hind tanklas peab jõudma alla 6€/kg

04

Vesiniku tootmine, pakendamine ja tarbimine

RAND HYDROGEN

Vesiniku tootmisvõimalused

- Steam methane reforming (SMR)
- Madaltemperatuurne elektrolüüs
- Kõrgtemperatuurne elektrolüüs
- Plasmalüüs

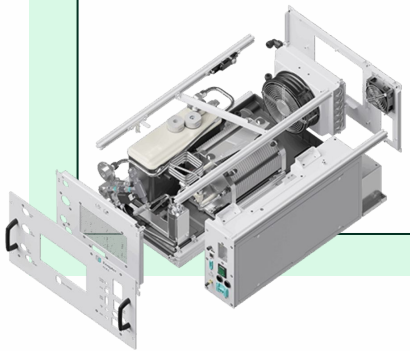
Steam methane reforming

1. $CH_4 + H_2O - CO + H_2$ (syngas)
2. $CO + H_2O - CO_2 + H_2$ (water-gas shift)

Tasakaalustamata võrrandid!

Madaltemperatuurne elektrolüüs

- Ultrapuhas vesi tehakse täpselt juhtivaks
- CA 60% vesinik ja 40% soojusenergia
- Peamiselt Leelis, PEM ja AEM tehnoloogiad.
- AEM väärismetallide vaba, kuid piirangud stacki diameetris
- PEM nõuab iriidiumi katalüsaatorit, mis ei ole lihtne probleem.
- Stagate Hydrogen toodab eestis leeliselisi elektrolüüsereid, millest üks ka varustab Eesti tanklaid lasnamäel.



Kõrgetemperatuurne elektrolüüs

- Toodab 150C veeaurust.
- CA 72% vesinik ja 38% soojusenergia
- Endotermiline, ehk et taaskasutab jääksoojust tõstes efektiivsust 100% juurde
- Odavad materjalid
- Pikk külmkäivitustsükkel, kuid saab madalal energial soojas hoida
- Bloom Energy TRL9
- Eesti tootja Elcogen

Clean

Our systems produce near zero criteria pollutants (NOx, SOx, and particulate matter) and far fewer carbon emissions than legacy technologies.

Reliable

Bloom Energy Server is designed around a modular architecture of simple repeating elements. This enables us to generate power 24 x 7 x 365.

Resilient

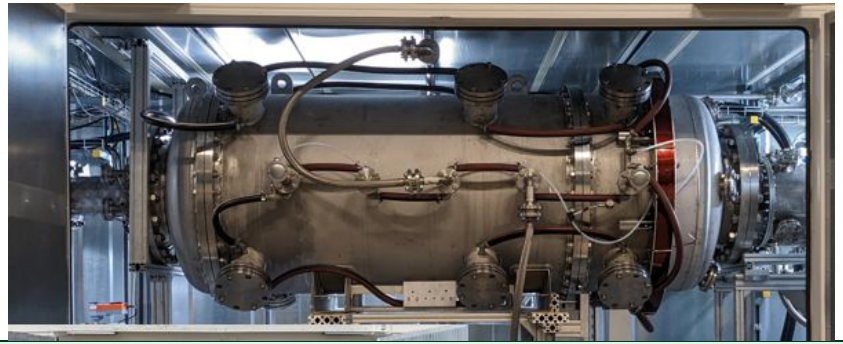
Our system operates at very high availability due to its fault-tolerant design and use of the robust natural gas pipeline system. The Bloom Energy Server has survived extreme weather events and other incidences and have continued providing power to our customers.

Simple Installation and Maintenance

The Energy Server is 'plug and play' and has been designed in compliance with a variety of safety standards. Bloom Energy manages all aspects of installation, operation and maintenance of the systems.

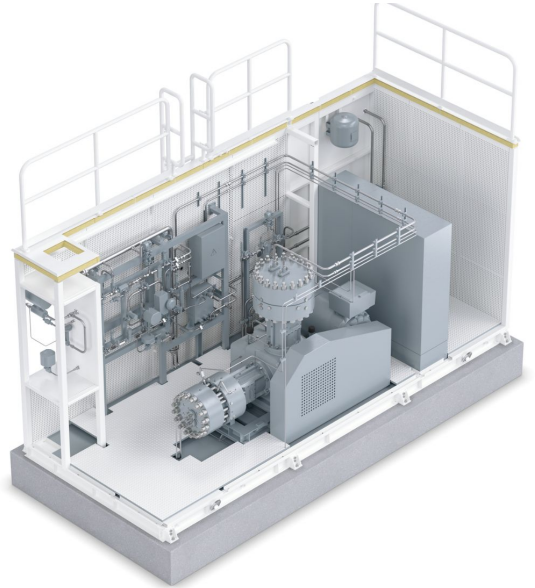
Plasmalüüs

- Plasma lõhub kambris hapnikuvabalt metaani vesinikuks ja puhtaks süsinikupulbriks
- Elektri mõttes 300% efektiivne
- Hind seisneb gaasi hinnas
- Süsinikule on turgu
- Biogaasiga süsiniknegatiivne
- Väga kõrge CAPEx



Vesiniku pakendamine kompressoritega

- Kg vesiniku (33.3kWh LHV) kokku surumisele (500-1000bar) kulub 3-9kwh
- Rõhu tõustes väheneb võime volüümi vähendada(Compressibility rate väheneb)
- Veokatele peetakse optimaalseks 350 bar.
- Peamised tehnoloogiad diafragma ja kuivkolvid



Vesiniku pakendamine silindritesse

4 tüüpi

1) Teras
2) Teras kaetud terasniidipõiminguga
3) Metall kaetud komposiitpõiming
4) HDPE pudel kaetud komposiitpõiminguga

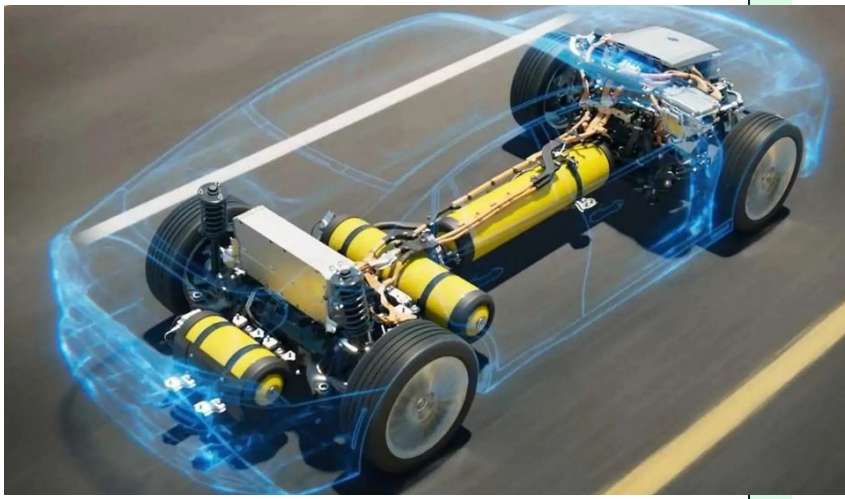
700bari juures kannab tüüp 4 süsteem ligi 1.7kwh kg kohta, mis on ca 8 korda rohkem, kui aku.

Vesiniku kasutamine

1. Sisepõlemismootor
    a. Kogu süsteem kõrgel rõhul
    b. Madal efektiivsus
2. Kütuseelement
    a. Efektiivsus kuni 60%
    b. Kõrge rõhk ainult paagis
    c. Vanandunud tehnoloogia

Sõidukid on ilmakindlad.

Sõiduulatus talvel oluliselt ei kannata.



Vesiniku kasutamine

Keemiatööstus:

1. Ammoniaagi tootmine (NH_3) on enamus praegusest kasutusest
2. e-Metanool
3. SAF
4. Taimeõlid

05

Vesiniku hind

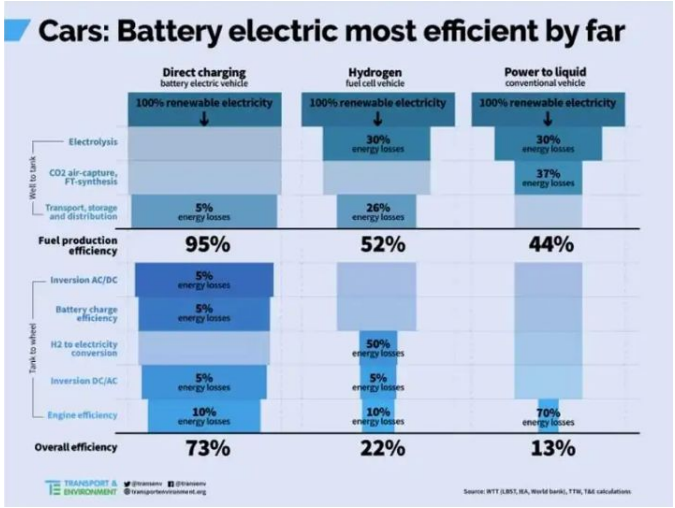
RAND HYDROGEN

Vesiniku hind

- Majanduslik loogika alates 500kW süsteemist (9kg/h)
- Kõrgtemperatuurne toodab 30% rohkem raha, aga miinimum turul 10MW
- SMRi pole mõtet investeerida, sest see ei lahenda probleeme ja hinnasurve pigem üles.
- Elektrolüüsil 70-80% hinnast dikteerib elektrihind.
- Tuuleenergia omahind kohapeal saaks olla 14€/MWH mis tähendaks diislist 3 korda odavamat kütuist.
- 50€/kWh elekter võimaldaks saavutada diisliga sama taseme
- Üle diisli hinna ei ole vesinikul muud rolli, kui nišina kaitsetööstuses ja tagavaraaenergialahendustes.
- Transport surugaasina lisab kg hinnale 4-6€ 1000km kohta

Vesiniku hind

- Efektiivsusvõrdlused ei arvesta rekupereerimist
- Keskmiselt 25% rekupereeritakse
- Sisepõlemismootoril on rekupereerimine vähem tõhus
- Sõitke akuga, kui vähegi saab



Allikas:
https://insideevs.com/news/332584/efficiency-compared-battery-electric-73-hydrogen-22-ice-13/

06

Vesiniku turvalisus

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Turvalisus

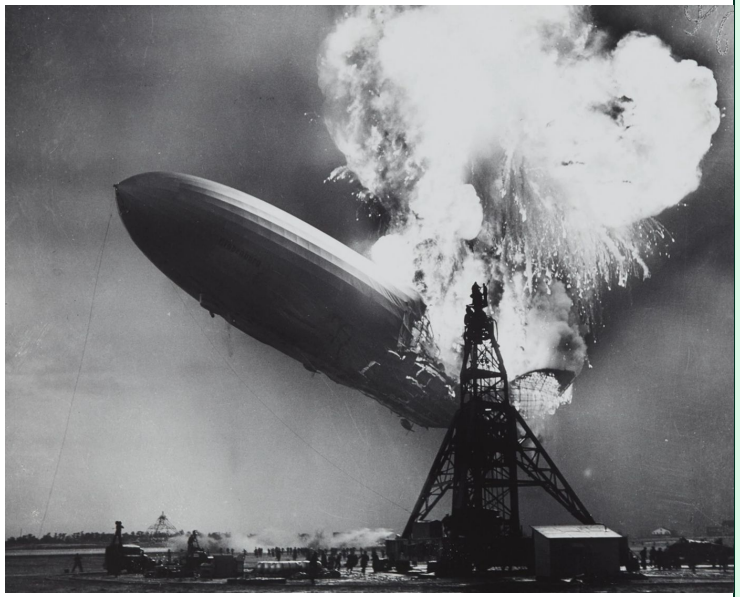
- Vesinik teeb ainult kahte asja, tõuseb ja hargneb.
- Kuna nii palju kardetakse, on turvalisus väga kõrgel tasemel.
- 0 Toyota Mirai paaki on plahvatanud
- Tüüp 4 paagid ei plahvata.
- CNG auto paakide plahvatused miskipärast rahvast ei häiri
- Vesiniku juures töötamine on puhas tegevus.
- Liitmikud on väga lollikindlalt tehtud ja lekete vältimine on selge.
- Puhas ja ohutu tegevus, eriti väliruumides.
- Vesiniku plahvatamisega lõppenud juhbtumid on lokaalsed ja väga väikese mõjuga, kuigi on olnud ka fataalseid.

Ohud

- Vesinik on tugeva plahvatusjõuga väga ohtlik kütus õiges kontsentratsioonis õhus
- Lekkeid ei saa tolereerida.
- Vesiniku veoautosid siiski siseruumis hoida ei taha, kui see ruum ei ole ehitatud vesiniku hoiustamist silmas pidades.
- Vesinik põleb aeglase lekke korral nähtamatult ja kiirgab väga vähe sooja. Leeke tuvastatakse UV kaameratega.
- Oht on siis, kui reegleid ei järgita.

Hindenburg

- ⅔ jäi ellu
- Mõtteeksperiment: Oleks seal olnud vesiniku asemel mistahes teine kütus, oleks kahju olnud suurem?



Allikas: https://en.wikipedia.org/wiki/Hindenburg_disaster#/media/File:Hindenburg_disaster.jpg

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THANK YOU!

info@randhydrogen.com

https://fuelcellsworks.com/2025/07/28/green-investment/stargate-hydrogen-secures-investment-from-repsol-to-drive-profitable-growth

https://www.bosch-hydrogen-energy.com/pem-electrolysis/pem-electrolysis-stacks/

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https://www.graforce.com/en/products/methane-pyrolysis

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https://fuelcellsworks.com/news/u-s-hydrogen-car-sales-were-up-in-2023-but-still-far-behind-evs

Hydrogen production methods

01

Steam Methane Reforming (SMR)

Inputs: Methane, Steam.

Outputs: H2, CO, CO2

Benefits: Low cost

Drawbacks: Greenhouse gas heavy. Large scale.

02

Ammonia /Methane Plasmalysis

Inputs: Methane, Electricity.

Outputs: H2, C

Benefits: Carbon neutral or negative. Low power requirement. Produces valuable carbon.

Drawbacks: Greenhouse gas heavy. Large scale.

03

Water Electrolysis

Inputs: Water/Steam, Electricity

Outputs: H2, O2

Benefits: Carbon neutral. Location independent. Abundant. Low cost with direct wind or hydro power. Safe and ultra clean. Small scale possible.

Drawbacks: Expensive from grid electricity.

04

Aluminium + water

Inputs: Aluminium powder, Water.

Outputs: H2, Al(OH), AlO(OH), Al2O3

Benefits: Very low tech and easy to transport. No need to transport hydrogen. Military uses. Ambient temp.

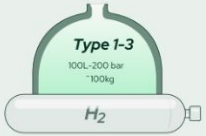
Drawbacks: Very expensive, unwanted byproducts.

Hydrogen containers

METHOD 01

Compressed hydrogen gas storage

Compressed hydrogen gas storage is one of the most common methods for storing hydrogen in cylindrical high-pressure vessels. The hydrogen gas is compressed to high pressure, depending on the specific application. This method offers a relatively simple and mature technology for hydrogen storage, and it is commonly used for medium- to small-scale applications, such as stationary long-term hydrogen storage as well as fuel cell vehicles and portable hydrogen-powered devices. However, the choice of pressure vessels for hydrogen is split into four types, each with pros and cons depending on the application.



Type 1 - 3 steel vessels

Depending on the type, it can have an external layer of composite wrapping for weight reduction but always contains a steel core.

PROS

- Cheap

CONS

- Heavy

Type 4 polymer and carbon fiber vessels

The polymer core is wrapped into several layers of carbon-fiber-based composites. Best for mobile solutions.

PROS

- Very light
- Extremely strong
- Safest solution

CONS

- Roughly 2-3 times more expensive than the Type 1-3 vessels

METHOD 02

Cryogenic liquid storage

Hydrogen can also be stored in a liquid state by cooling it to extremely low temperatures (-253 degrees Celsius or -423 degrees Fahrenheit). In this method, hydrogen is liquefied and stored in insulated tanks. This method offers higher energy density than compressed gas storage, allowing for a larger quantity of hydrogen storage in a given volume. However, cryogenic liquid storage comes with plenty of losses in efficiency and the challenge of hydrogen just boiling off. Cryogenic storage is commonly used where hydrogen is essential, but room is limited—for example, in the space industry. Liquid storage is also considered for long-distance maritime transportation.

02

H2 for NatGas grid

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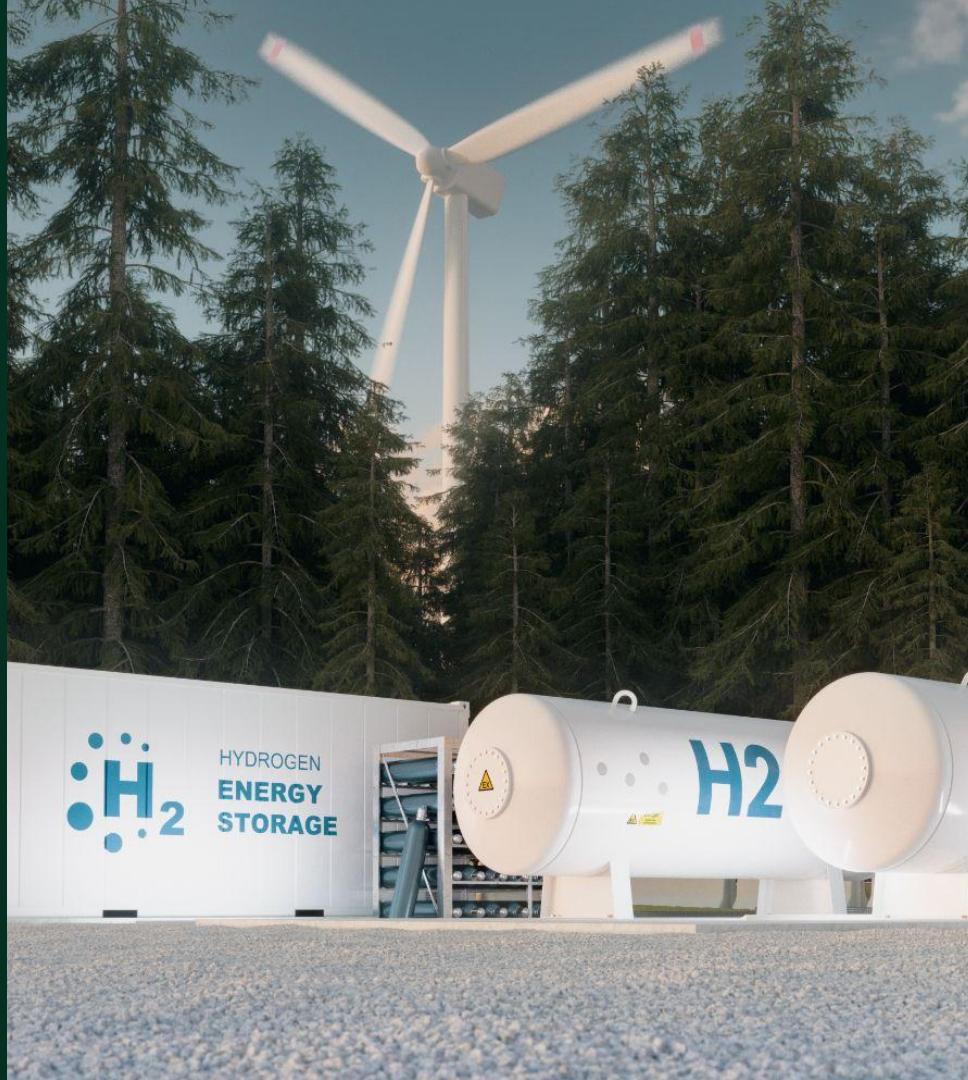


TURNKEY GREEN HYDROGEN PRODUCTION

Lifetime 25-30 years

Water + Grid Electricity > SOEC Electrolysed H2 (11.4MW) > Natural gas grid (10% H2 blend up to 70bar)

Inputs

Water 9L/kg H2

Electricity **0.08 USD/kWh**

CapEx **28m USD**

2.3 MW heat (Captured heat)

Outputs

H2 97%-99.999% purity

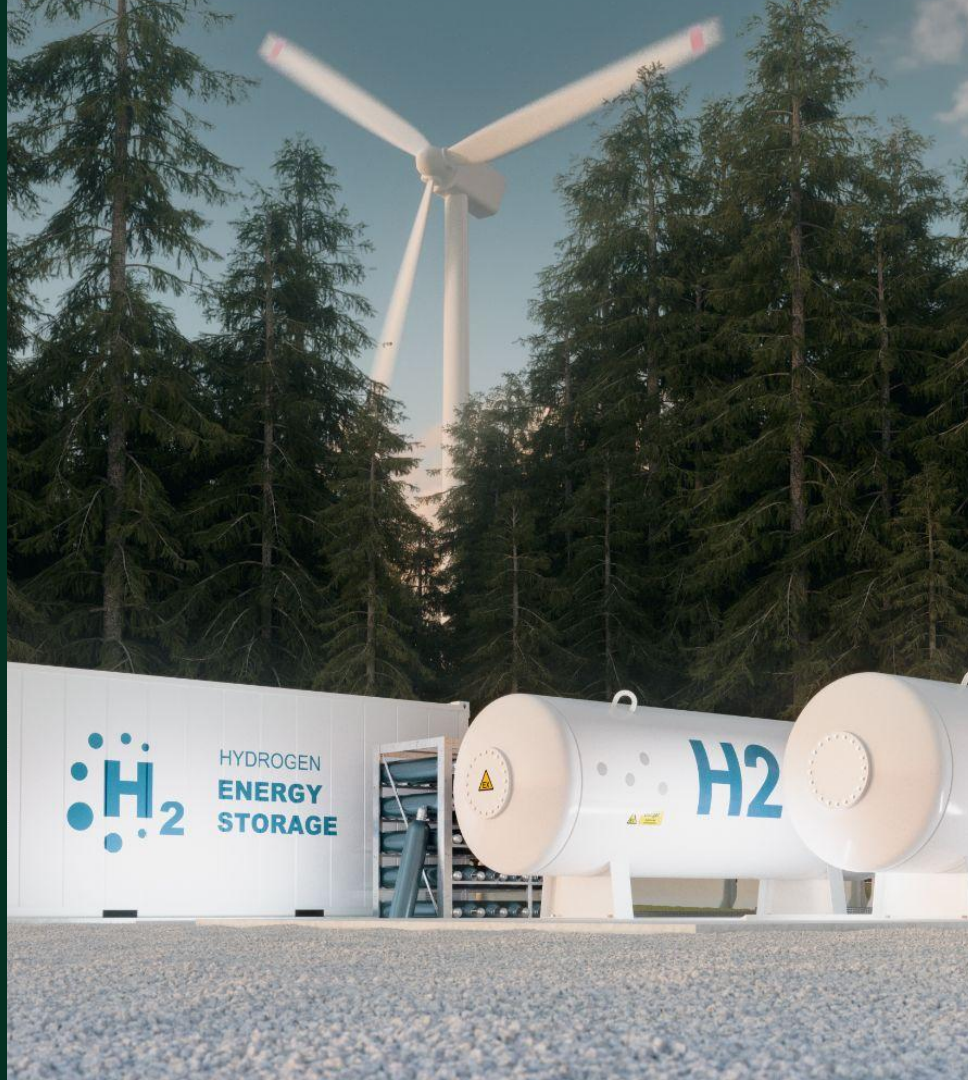
Sales price **5USD/kg**

ROI 10 years (without grants)

2.8m USD annual net revenue

02

H2 for mobility



RAND HYDROGEN

Hydrogen production for mobility

Lifetime 25-30 years

Water + Grid Electricity > SOEC Electrolysed H2 (11.4MW) > H2 Fuel Station

Inputs

Water 8L/kg H2

Electricity **0.08 USD/kWh**

CapEx **28m USD**

2.3 MW heat (Captured heat)

Outputs

H2 99.999% purity

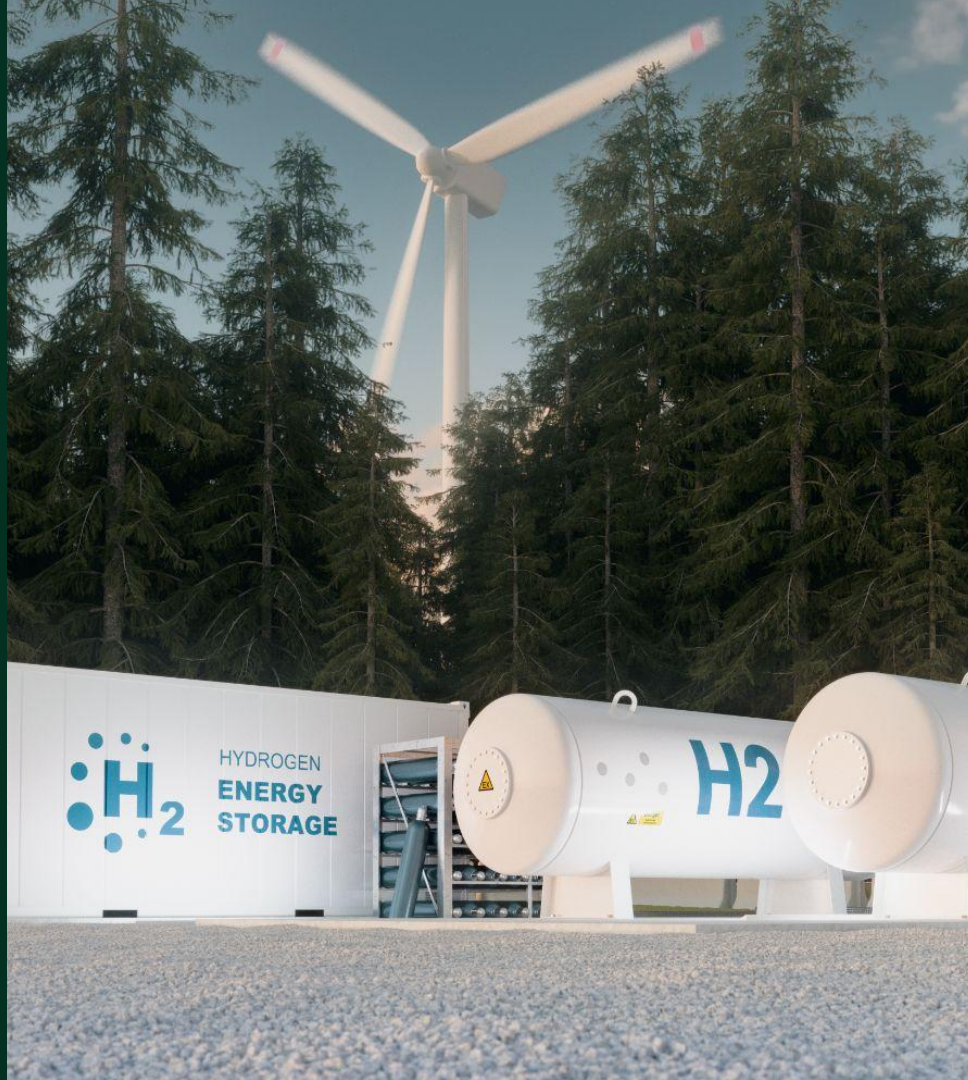
Sales price **6USD/kg**

ROI 5.5 years (without grants)

5m USD annual net revenue

02

H2 for power grid supply



RAND HYDROGEN

TURNKEY GREEN HYDROGEN PRODUCTION

Lifetime 25-30 years

Water + Grid Electricity > SOEC Electrolysed H2 (11.4MW) > FUEL CELL (PEM or SOEC)

Inputs

Water 8L/kg H2

Electricity **0.08 USD/kWh**

CapEx **45m USD**

2.3 MW heat (Captured heat)

Outputs

Electricity

Sales price, capacity and ROI dependent on power purchase terms

03

SERVICES

RAND HYDROGEN

Services

01

Feasibility studies

Our 3 step analysis provides the most cost-effective and detailed way to analyse the complete hydrogen production vertical. We account weather data, power production costs up to production, storage and distribution costs.

02

Turnkey hydrogen production solutions

Rand Hydrogen helps you with plant designing, and equipment procurement with installation and construction.

03

Maintenance

Our engineers will make sure the plant operation is smooth and effective.

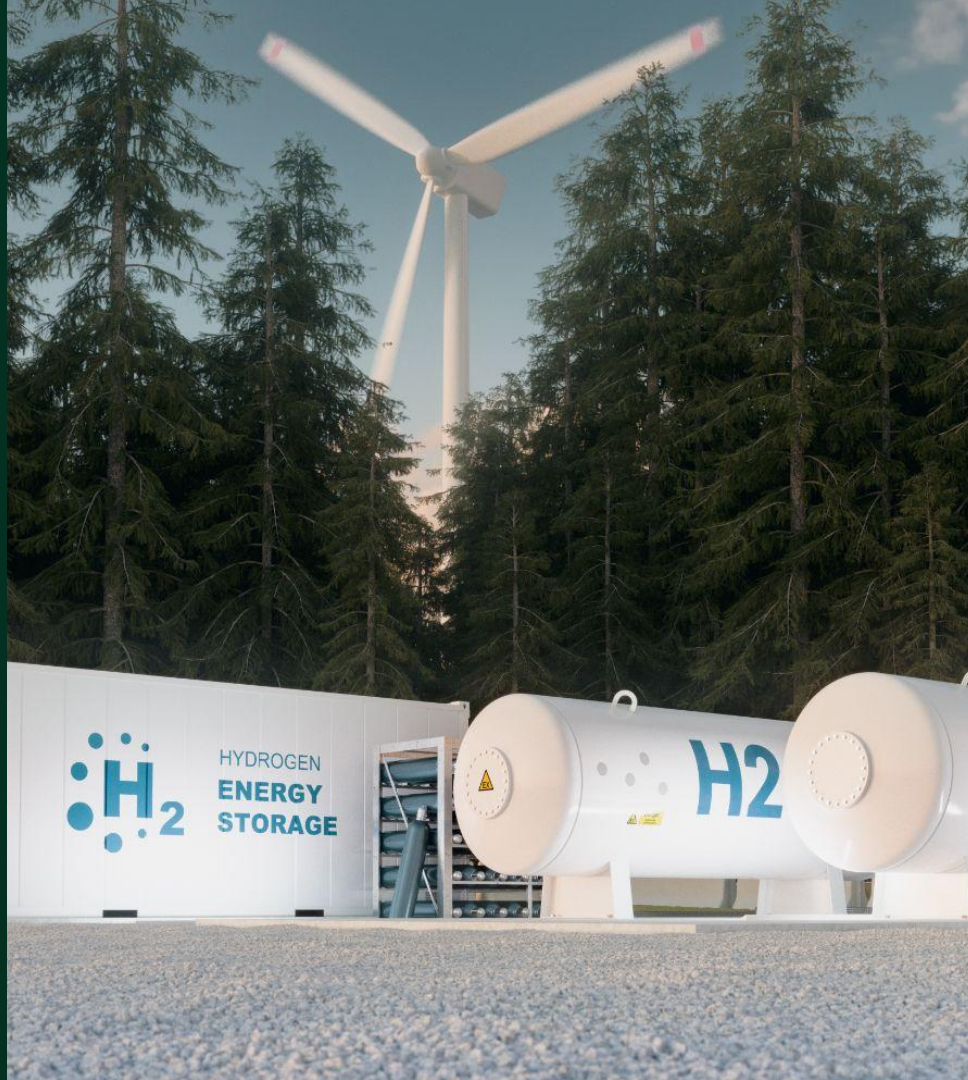
04

Power-to-X

Rand Hydrogen provides EPCM services for Power-to-X projects with hydrogen production.

04

PROJECTS



RAND HYDROGEN

PROJECTS AND OFFERINGS

2024 BIGGEST H2 PRODUCTION ESTONIA

550kw alkaline electrolyzer
1300kg of H2 per week.

Status: In delivery

PROJECTS AND OFFERINGS

Q4 2025 green ammonia Paldiski

500kg of H2 needed per hour
20 - 25 thousand tonnes of ammonia per year

Status: FID reached. 17 million € grant awarded. Supplier contract negotiations. Bloom Energy SOEC 18MW

05

SOLID OXIDE Electrolysis and Power generation products

Accredited representative

RAND HYDROGEN

Trusted representative of

Bloomenergy®

- **SOEC**
- **SOFC**
- **SOFC Energy Servers**

SOEC

Bloomenergy

- Operating range 20%-100%, 5% standby
- Efficiency **37.5kWh/kg LHV (88.8%)**
- Stack lifetime 6 years
- BOP lifetime 30 years
- Endothermic electrolysis (Steam input)
- Ambient temperature -20C to +45C
- Origin: USA
- Medium to large scale commercial applications

SOFC

Bloomenergy

- Operating range 20%-100%, 5% standby
- Feedstock options: **Hydrogen (99.9%), Hydrogen methane blend, Methane, Methanol**
- H2 thermal efficiency **52%**
- Methane thermal efficiency **64%**
- BOP lifetime 30 years
- Recycleable heat
- Ambient temperature -20C to +45C
- Origin: USA
- Small to large scale commercial applications

SOFC Energy Server

Clean

Our systems produce near zero criteria pollutants (NOx, SOx, and particulate matter) and far fewer carbon emissions than legacy technologies.

Reliable

Bloom Energy Server is designed around a modular architecture of simple repeating elements. This enables us to generate power 24 x 7 x 365.

Resilient

Our system operates at very high availability due to its fault-tolerant design and use of the robust natural gas pipeline system. The Bloom Energy Server has survived extreme weather events and other incidences and have continued providing power to our customers.

Simple Installation and Maintenance

The Energy Server is 'plug and play' and has been designed in compliance with a variety of safety standards. Bloom Energy manages all aspects of installation, operation and maintenance of the systems.

Bloomenergy®

- Plug and play (min 330kw)
- Operating range 20%-100%, 5% standby
- Feedstock options: **Methane, Blended Hydrogen**
- Cumulative electrical efficiency 65–53% (LHV net AC)2
- Heat rate (HHV) 5,811–7,127 Btu/kWh
- Ambient temperature -20C to +45C
- Noise <65 dBA @10 ft
- Origin: USA
- Small to large scale commercial applications

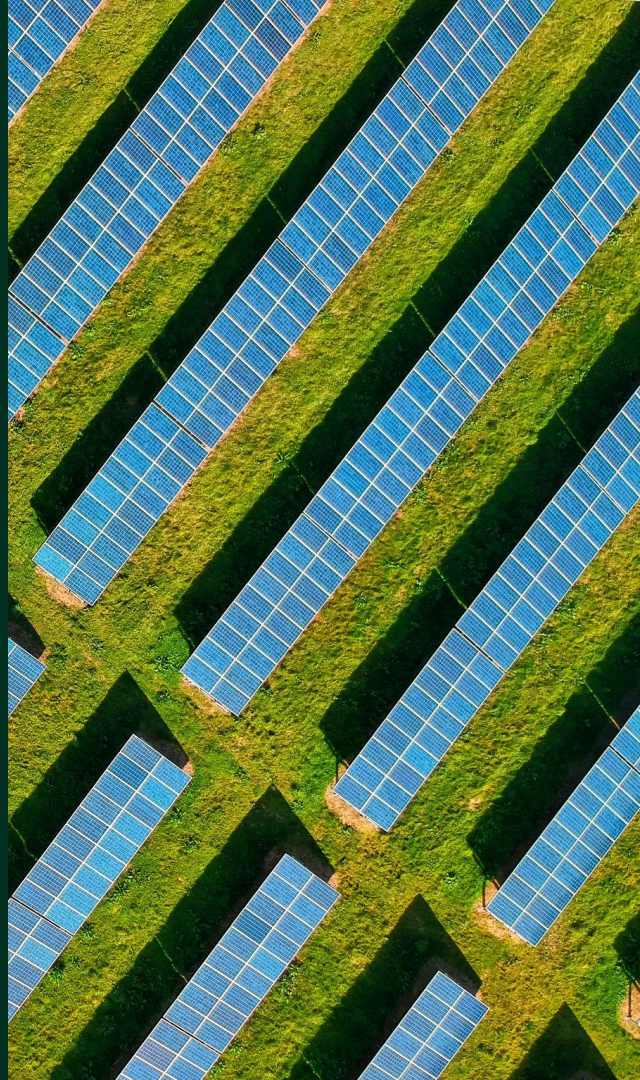
About

Bloomenergy®

- Established 2001
- First Solid oxide operating unit 2006
- 2010 solid oxide deployments in Google, Walmart, Coca-Cola, Fedex, Bank of America and more.

06

REFERENCES



RAND HYDROGEN

SOFC installation

Bloomenergy®

delmarva power

https://www.bloomenergy.com/customer/delmarva-power/

"Our Bloom Energy Servers in New Castle, Delaware rode through Hurricane Sandy without incident and continued to feed power to the regional power grid despite all the challenges the storm presented."

– Delmarva President Gary Stockbridge

- SOFC 30MW
- Location: Delaware

SOEC demonstration site

Bloomenergy®

https://newsroom.bloomenergy.com/news/bloom-energy-demonstrates-hydrogen-production-with-the-worlds-largest-and-most-efficient-solid-oxide-electrolyzer

- SOEC 3.6MW
- Location: Moffett Field research facility in Mountain View, Calif

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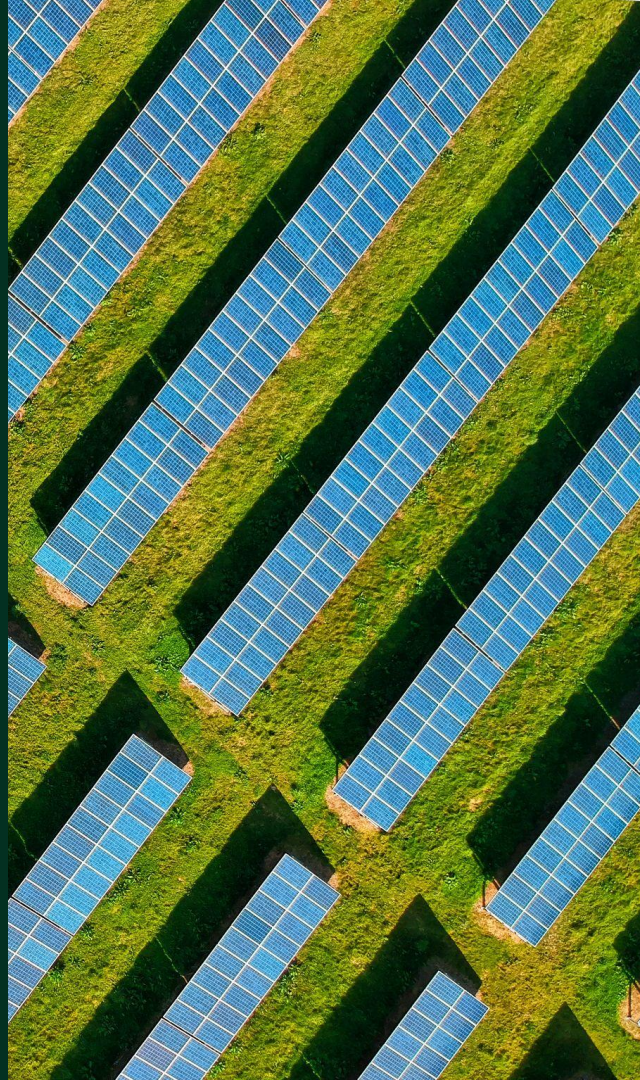
Other solutions



RAND HYDROGEN

Power UP auxiliary power solutions

Power UP ENERGY TECHNOLOGIES

- Power output **per module 400-6000W**
- Energy storage cost approx 10€/KWH
- Thermal efficiency **59%**
- Ambient operating temperature -5C to +40C
- Fueled by gaseous hydrogen (99.95%)
- Peak power from **Lithium Batteries**
- Safe indoors
- Used for **Telecom Towers, Hospitals, Pharmacies, Railway Maintenance** etc.

Plasmalysis

- 100 kg output H2 per MWh
- 400kg input CH4 per MWh
- 300kg output C per MWh
- Low footprint

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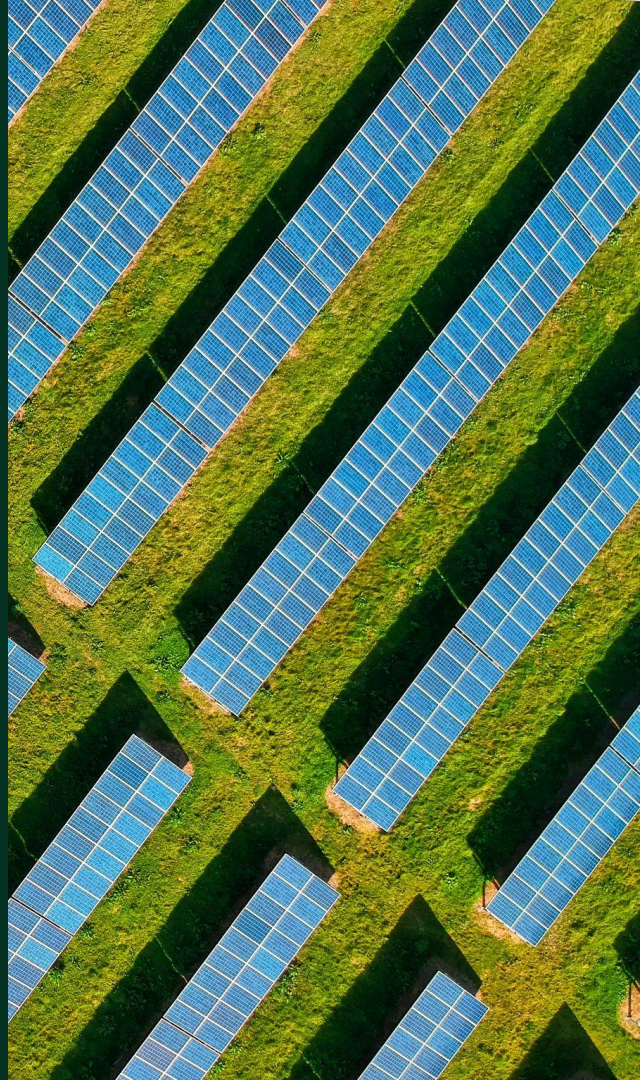
TEAM



RAND HYDROGEN

Core Team

Hando Rand

CEO

ICT Entrepreneur, GreenTech/DeepTech investor.

Raimond Pääru

CTO

Engineer with years of experience managing renewable energy EPC services for large energy companies.

Markus Pertelson

Lead Project Designer

Designed in total of 50MW of renewable energy plants for large energy companies.

Erik Kuus

Distribution and mobility

7 years as a manager in Toyota Motor Europe. Hydrogen storage, refueling and mobility expert.

Collaboration

RAND HYDROGEN

In collaboration with:

Bloomenergy

SIEMENS

PowerUP ENERGY TECHNOLOGIES

WENGER Engineering GmbH